National Wireless Communications Technology Roadmap

2008

Version 1.0

Prepared by
MIMOS BHD

Ministry of Science, Technology and Innovation

(MOSTI)

Roadmap Content

1. Introduction

The wireless communication sector represents one of the most important arenas of research and expansion in Malaysia. The last two decades has been considered to be the era of wireless communications being led by two major trends: the outburst of wireless multiple access communications, offering mobility to the telephone users and the mobile multimedia. The increasing number of mobile telecommunication subscribers cause great concern to the research community and they are in the process of finding solutions to accommodate these customers.

The National Wireless Communications Technology Roadmap serves as the basis to drive the national centers of excellence (CoEs) in the area of concern. The CoEs will be established based on the expertise available at R&D organization.

Moreover, the roadmap will serve as a guide to the Ministry of Science, Technology and Innovation (MOSTI) for approving research proposals seeking scientific and technical grants. The roadmap could serve as the basis to drive a concerted effort in R&D activities in wireless communications nationwide (e.g., through top-down initiatives, etc).

As mentioned earlier, to be at the cutting edge of wireless technologies and hence, to excel in those areas, it is quintessential to identify the latest technology trends and challenges. Hence, it is necessary to keep this roadmap very much alive by updating it on a regular basis. This roadmap will provide insights to the local academics and the researchers to work on technologies of the future.

The collective belief is that this roadmap will serve as a useful tool for carrying out R&D in wireless communications technologies, based on trends and challenges, to enable Malaysia to be at par with other developing countries.

2.1 Global Scenarios: User Expectation

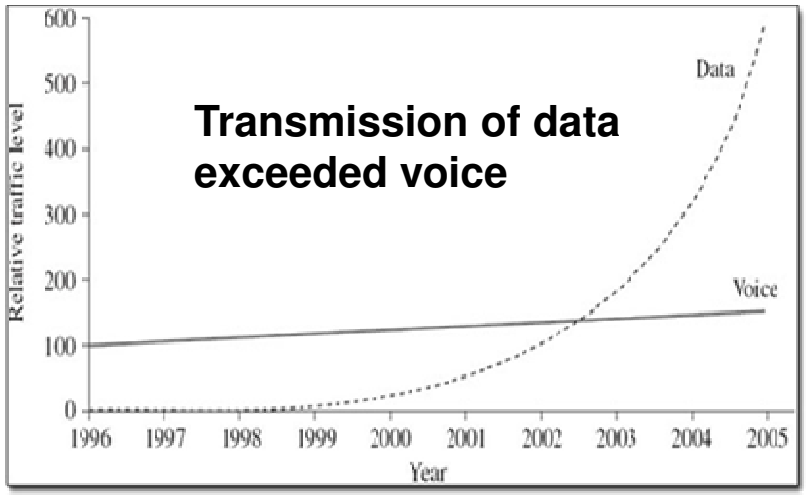
Being able to enjoy access to voice and data on ***anytime*** and ***anywhere*** basis at any platform has always been the focus of the wireless communication communities.

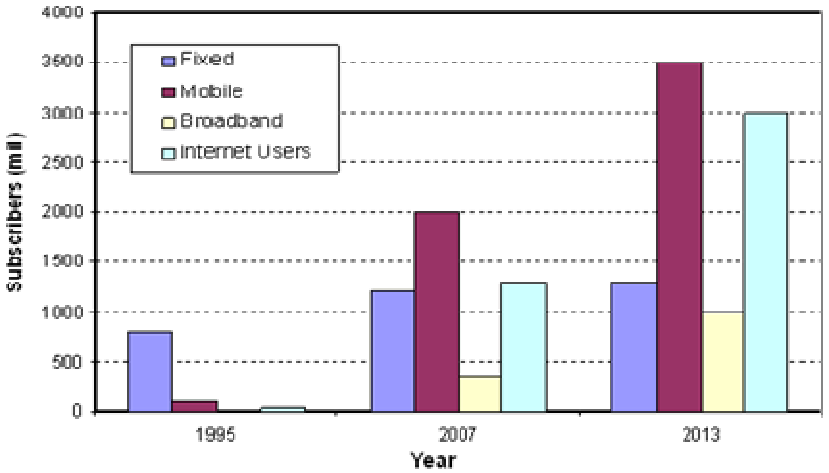
Users are expecting a ***dynamic***, ***continuing stream*** of content-rich applications, services that are ***ubiquitous*** and available ***across a range of devices*** using a ***single subscription*** for ***any access***.

In year 2002, the transmission of the data traffic started to exceed voice traffic. The numbers of mobile subscribers and internet users have also recorded a significant growth over the past few years.

In European, the WWRF (Wireless World Research Forum) Vision has set principles for wireless world from user perspective:

- Users are in control through intuitive interactions with applications, services and devices
- Services and applications are personalized, ambient-aware, and adaptive (I-centric) -ubiquitous from the point of view of the user
- Seamless services to users, groups of users, communities and machines (autonomously communicating devices) irrespective of place and network and with agreed quality of service
- Users, application developers, service and content providers, network operators and manufacturers can create efficiently and flexibly new services and business models
- There is awareness of, and access to, appropriate levels of reliability, security and trust worthiness in the wireless world





Source:

- *"Protocols in multi-service networks", The Open University (http://openlearn.open.ac.uk/mod/resource/view.php?id=175837&direct=1)*
- *Frost &Sullivan, Next Generation Telecoms 2008 (Global NGN update)*
- *"Global Visions for the Future Wireless World from the WWRF", IEEE VEHICULAR TECHNOLOGY MAGAZINE, JUNE 2006*

2.1 Global Scenarios: User Expectation

User's Expectations for 4G* Mobile Systems

Service and features expected for 4G Mobile

- ♦**Freedom in Time**
- ♦**Freedom in Space**
- ♦**Freedom in Use of Features**

New Lifestyles Realized by 4G Mobile

- **Enriched and Cultural Life**
  - Enriched life – able to communicate with friends and families anytime
  - A cultural life – able to receive information of your choice and easily obtain the right entertainment you like
- **More Flexible and Diversified Life**
  - Flexible and Diversified Life – able to work regardless of home circumstance
  - Environment that enables various people to freely participate in social activities
- **More Comfortable and Safer Life**
  - More Comfortable and Safer – safety is ensured anytime, anywhere
  - Convenient and Comfortable Life – able to access services on highly convenient networks in a secure manner
- **More Personal and Convenient Life**
  - Personal Life – possible to freely select from a wide range of services based on individual preferences
  - Extremely convenient life – what you want to do now can be done right away

*** 4G:**

- 4G (also known as Beyond 3G) is a system that able to provide a comprehensive IP solution where voice, data and streamed multimedia can be given to users on an "Anytime, Anywhere" basis, and at higher data rates than previous generations.
- The major goals are integration and convergence among different types of wireless networks with the wireline backbone.

Source:

- *March 29th, 2005, CJK-05, Tokyo, JAPAN*
- *Wikipedia: http://en.wikipedia.org/wiki/4G*
- *"Interoperability in Future Wireless Communications Systems: A Roadmap to 4G", June, 2007, Microwave Review*

2.1 Global Scenarios: User Expectation

Objectives of IMT-2000* (3G) and IMT-Advanced** (4G) proposed by ITU-R# from user perspectives

Perspective	Objectives
END USER	• Ubiquitous mobile access • Easy access to applications and services • Appropriate quality at reasonable cost • Easily understandable user interface • Long equipment and battery life • Large choice of terminals • Enhanced service capabilities • User-friendly billing capabilities

Note:

* **IMT-2000:** International Mobile Telecommunications-2000 (IMT-2000) is the global standard for third generation (3G) wireless communications, defined by a set of interdependent ITU Recommendations

** **IMT-Advanced:** International Mobile Telecommunications - Advanced (IMT-Advanced) is a concept from the ITU for mobile communication systems with capabilities which go further than that of IMT-2000.

ITU-R: The International Telecommunication Union Radiocommunications (ITU-R) Working Party 8F is responsible for the overall radio frequency spectrum and radio system aspects of IMT-2000 and systems beyond

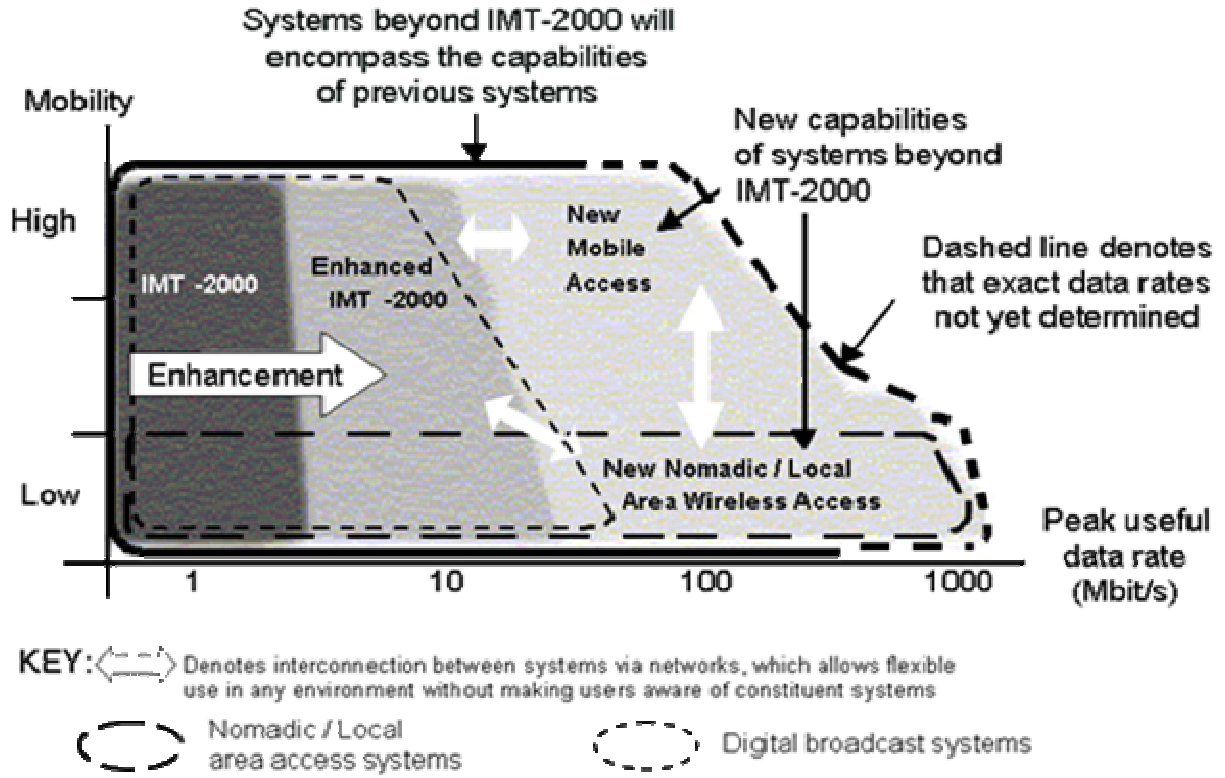
Source:

- *"Protocols in multi-service networks", The Open University (http://openlearn.open.ac.uk/course/view.php?id=2542&topic=all)*

2.2 Global Scenarios: Global Wireless Technology Trends

Framework showing performance improvement in terms of mobility and data rate from IMT-2000 to IMT-Advanced

The IMT-Advanced, or commonly known as, 4G systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-2000 or 3G. Such systems are recommended by ITU to be able to provide access to a wide range of telecommunication services including advanced mobile services and high quality multimedia applications, supported by both mobile and fixed networks. However, the standards of 4G will not be released till 2009



Source:

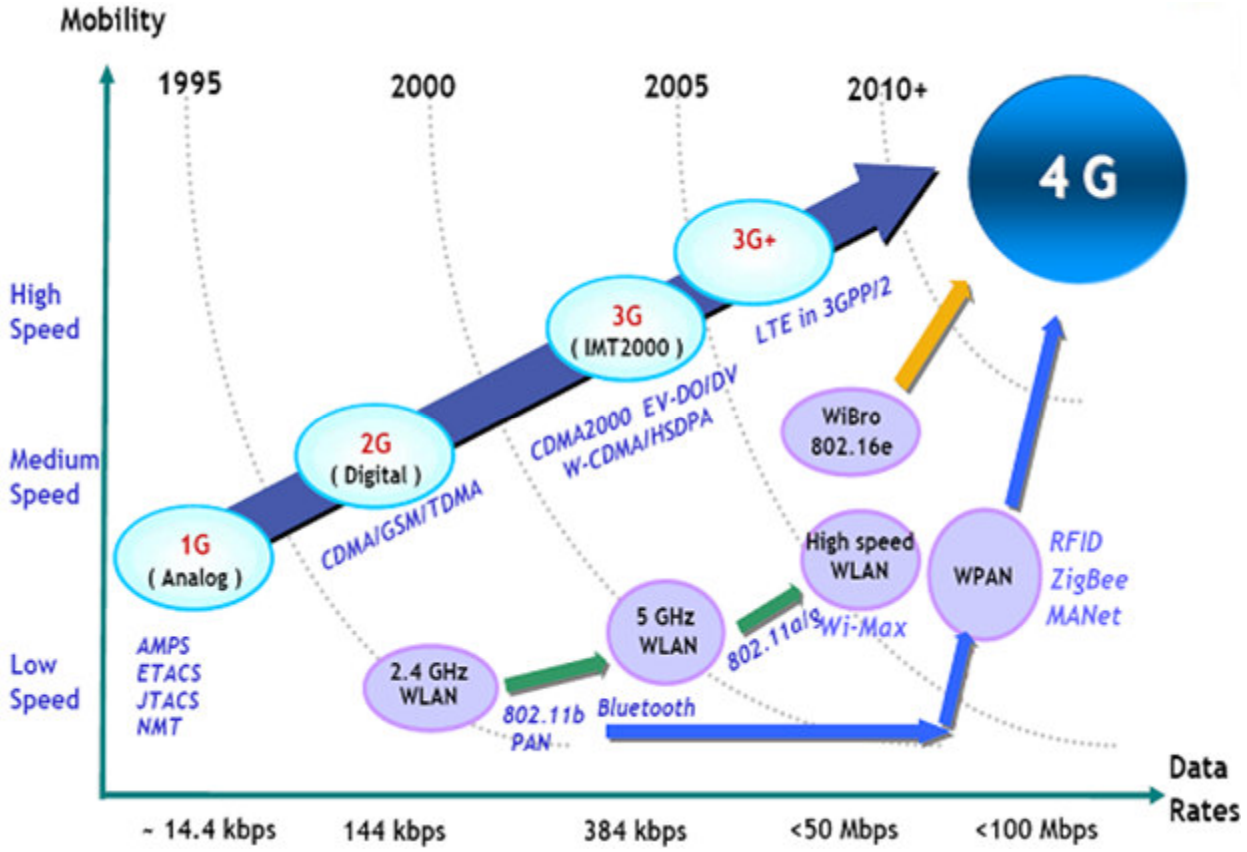
- *Recommendation ITU-R M.1645*
- *"Summary of ITU-R WP 8F work towards IMT-Advanced and the vision for the future, including examples of applications", JoséM. Costa, Senior Manager, Wireless Access Standards, Nortel Networks*

2.2 Global Scenarios: Global Wireless Technology Trends

Mobile communications roadmap showing the convergence of various technologies towards 4G

Key features of IMT-Advanced:

- Convergence among mobile/wireless systems
  - Provide seamless connection
  - Various services & QoS satisfying users' demand
- Differences from 3G:
  - Data rate: 100Mbps for high mobility, 1Gbps for low mobility
  - Provision of similar degree of QoS to wireline communication service
  - Global roaming
  - Handover between heterogeneous access networks
  - All IP network



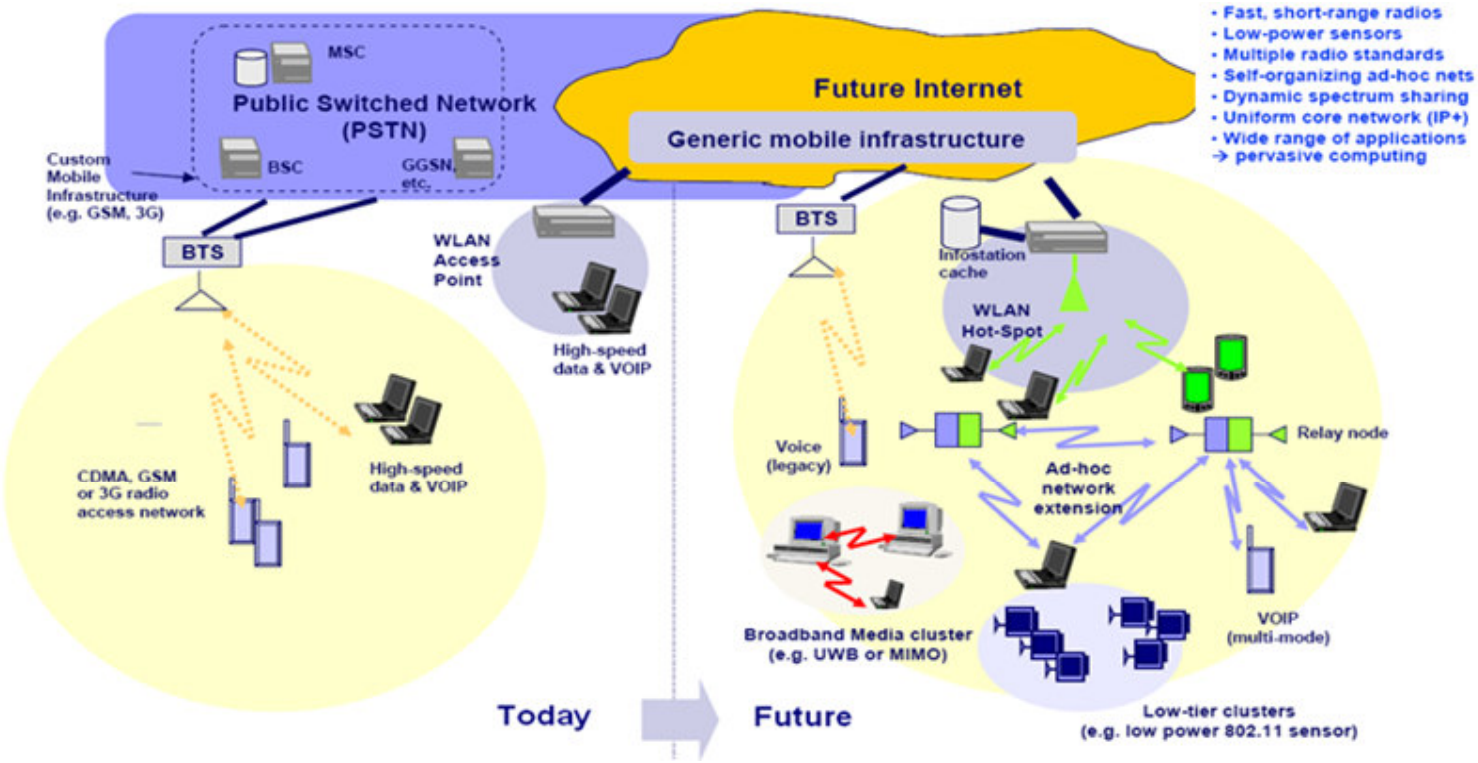
Source:

- *"3G LTE & IMT-Advanced Service, HSN 2006, February 22-24, 2006, Dr. Hyeon Woo Lee, Global Standards & Research, SAMSUNG ELECTRONICS*

2.2 Global Scenarios: Global Wireless Technology Trends

Future Wireless Network leading toward pervasive computing

With its strength in the silicon based integration, Intel had proposed to pull together computing and networking architectures to create integrated devices for the converged world. With this: ***All computers will communicate, and all communications devices will compute***. This is the fundamental step toward having ***pervasive computing*** in the ***ubiquitous world***.



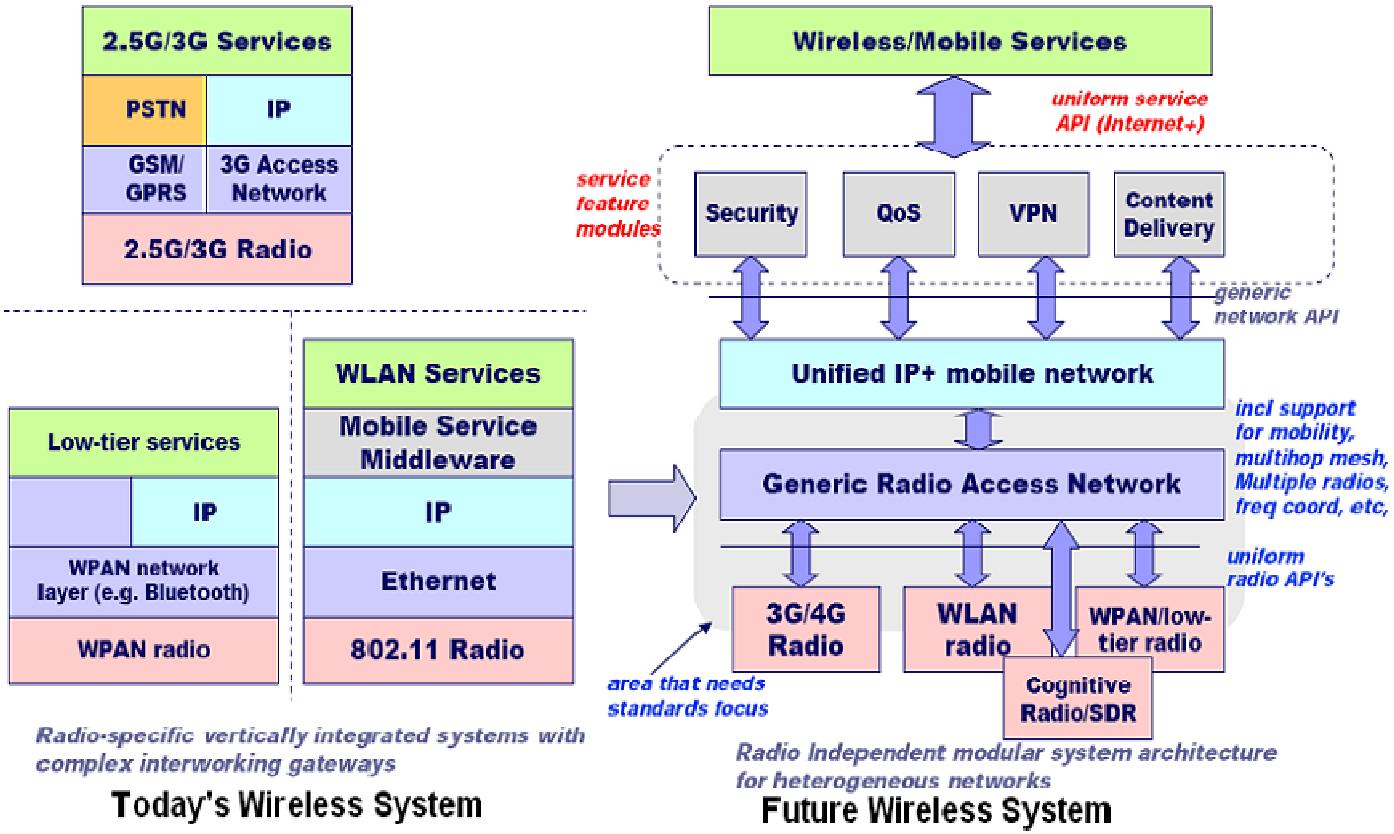
In the pervasive computing environment, the wireless networks is able to provide seamless Internet extension from wireless wide area network to wireless local area networks and high speed short-range communications. Cognitive radios, that enable dynamic spectrum sharing, increase the efficiency of spectrum utilization (through exploring the unused spectrum) to avoid wireless traffic jams. Self-organizing ad-Hoc networks formed by co-operating nodes form temporary networks to cater for dynamic network topology, which is decentralized, ever changing and the nodes may move around arbitrarily.

Source:

- *"Future Directions in Wireless Technology and the Path to Pervasive Computing", D. Raychaudhuri, IEEE PerCom 2006, March 15, 2006, WINLAB, The State University of New Jersey*
- *"Intel's Singer calls for 'platform-oriented' tools", 12 Apr 2005, EE Times*

2.2 Global Scenarios: Global Wireless Technology Trends

Next generation protocol architecture showing the convergence of heterogeneous networks



Today's network systems, eg. WWAN, WLAN and WPAN, are radio specific and vertically integrated.

The future heterogeneous networks (including WWAN, WMAN, WLN and WPAN) will converge on IP platform to provides various types of services. They are radio independent with modular system architecture, thanks to the advancement of cognitive radio and software defined radio.

Source:

- *"Future Directions in Wireless Technology and the Path to Pervasive Computing", D. Raychaudhuri, IEEE PerCom 2006, March 15, 2006, WINLAB, The State University of New Jersey*

2.3 Global Scenarios: Global Initiatives

Initiatives showing the scenarios of future wireless world

Country	Initiatives	Scenarios	Characteristics/Challenges
USA	• MIT Project Oxygen scenarios	• Business conference – 3 co-workers collaborate using rich media on 3 continents • Guardian angel – Jane and Tom and elderly couple, are able to stay in their home through an augmented environment • Field trip – Students take a field trip to New York City, where they visit a museum, check into a hotel, see a Broadway play, etc.	• Pervasive computing • Ubiquity • Human-centered
Japan	• NTT DoCoMo "Vision 2010" scenarios	• Multipoint video conference with simultaneous language interpretation • Point to Point 3D Telepresence • Multiparty Mobile Telepresence • Virtual Golf Game • Automatic Driving • Smart Coffee Kiosk	• Mobile Multimedia • Anytime, Anywhere, Anyone • Global Mobility Support • Integrated Wireless Solution • Customized Personal Service
Europe	• ETSI/TIA Project MESA (Mobile broadband for Emergency and Safety Applications) scenarios (2000)	• Remote patient monitoring • Mobile robotics • ESA firefighter	• Broadband • Digital • Mobile wireless

2.3 Global Scenarios: Global Initiatives

Initiatives showing the scenarios of future wireless world

Country	Initiatives	Scenarios	Characteristics/Challenges
Europe	• ISTAG scenarios for Ambient Intelligence in 2010	• 'Maria' Road Warrior - Personal ambient communicator; Could be achieved relatively early. • 'Dimitrios' and the Digital Me' (D-Me) - Connecting people and expressing identities; Also near term. • 'Carmen': traffic, sustainability & commerce - Traffic optimization; Further out on the time horizon. • Annette & Solomon in the Ambient for Social Learning - Social learning by connecting people and creating a community memory; Probably the furthest out.	• Ubiquitous computing • Ubiquitous communication • Intelligent User Friendly Interfaces • Awareness • Intelligence • Adaptable • Very unobtrusive hardware • A seamless mobile/fixed web-based communications infrastructure • Dynamic and massively distributed device networks • A natural feeling human interface • Dependability and security
	• University of Oulu. Project Paula CyPhone "Taxicab" scenario	• Airport indoor service discovery – finding a printer in a public space. • Outdoor hotel service discovery – discovering hotel rooms to rent. • University indoor navigation – finding a room using conformally mapped guidance. • Outdoor hotel booking – reserving a hotel room. • Electronic taxi fee payment – electronic payment of taxi fare.	• Efficient ways for outside navigation and displaying information using mobile devices

2.3 Global Scenarios: Global Initiatives

Other Initiatives

- u-Taiwan for Ubiquitous Network Society *(http://www.utaiwan.nat.gov.tw)*
- Singapore Sentient Computing *("Singapore Infocomm Foresight 2015", IDA Singapore)*
- IT839 Strategy to realize a u-Korea *(Korea IT839 Strategy, 2004)*
- ANA (Autonomic Network Architecture) Project *(European Sixth Framework Program)*
- FIRE (Future Internet Research and Experimentation) *(European Seventh Framework Program)*
- CASCADAS (Component-ware for Autonomic Situation-aware Communications, and Dynamically Adaptable Services) *(http://www.cascadas-project.org/)*
- Bio-inspired Networks (BioNETs) *(European Sixth Framework Program)*
- PlanetLab – An open platform for developing, deploying and accessing planetary-scale services *(http://www.planet-lab.org/)*
- Disappearing Computer (Global Smart Space GLOSS in UK) *(The Disappearing C o m p u t e r European Commission - US National Science Foundation Strategic Research Workshop, Vienna, Austria, 23 – 24 April 2004)*

2.3 Global Scenarios: Global Initiatives

RAND* Report: The Global Technology Revolution 2020

Technically Feasible Technology Applications That Are Likely to Be Implemented Widely in 2020:

1. Cheap solar energy
2. **The Internet**
3. Filters and catalysts for water purification
4. **Rural wireless communications**
5. **Ubiquitous information access**
6. Green manufacturing
7. Targeted drug delivery
8. Rapid bioassays
9. Tissue engineering
10. **Ubiquitous RFID tagging**
11. Hybrid vehicles
12. Improved diagnostic and surgical methods
13. Quantum cryptography
14. Drug development from screening
15. Body monitoring and control for disease management
16. Smart systems

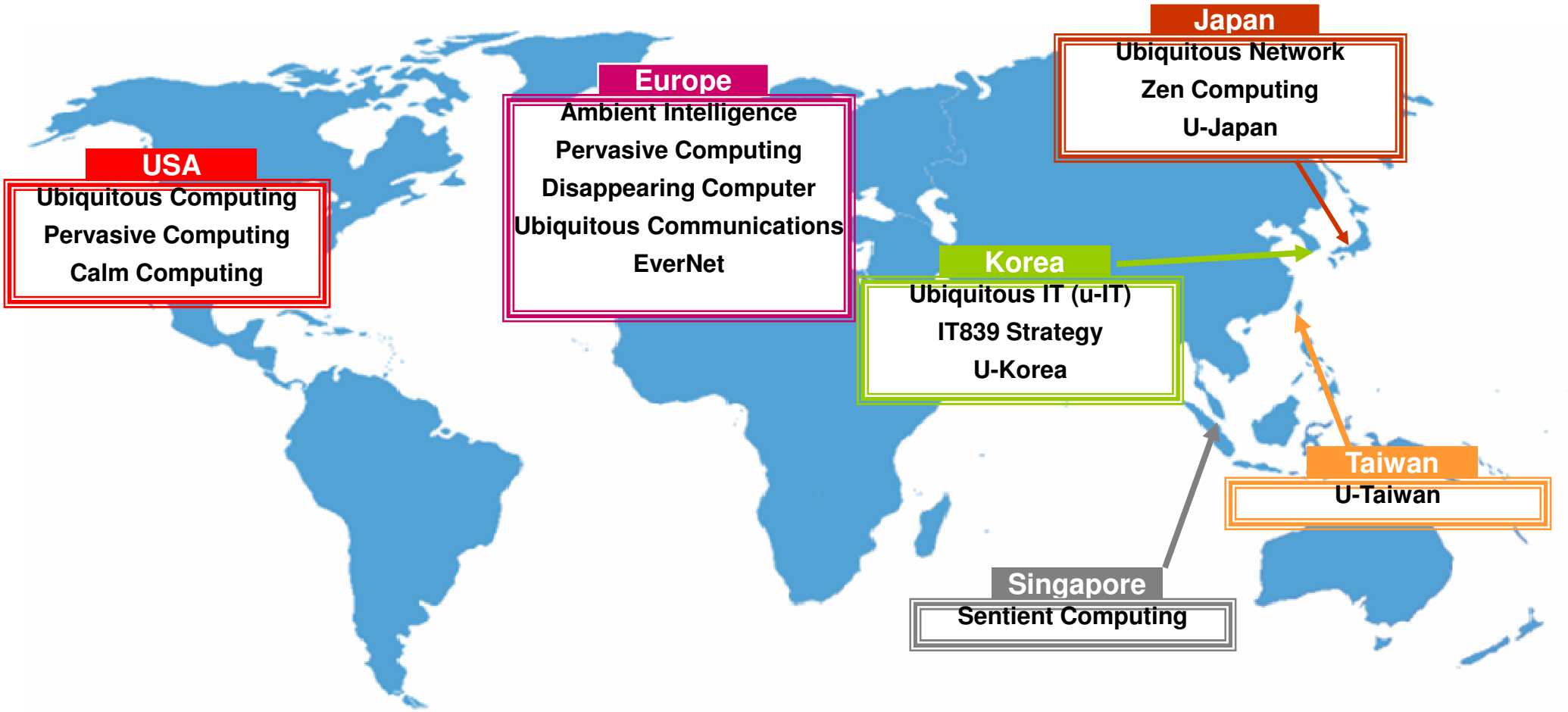
Out of 16 areas identified that are feasible to be implemented, 4 areas are pointing toward ubiquitous scenarios

* The RAND Corporation is a nonprofit institution that helps improve policy and decision making through research and analysis in USA.

Source:
- *RAND report: "The Global Technology Revolution 2020, In-Depth Analyses", 2006*

2.3 Global Scenarios: Global Initiatives

Terminologies used Worldwide



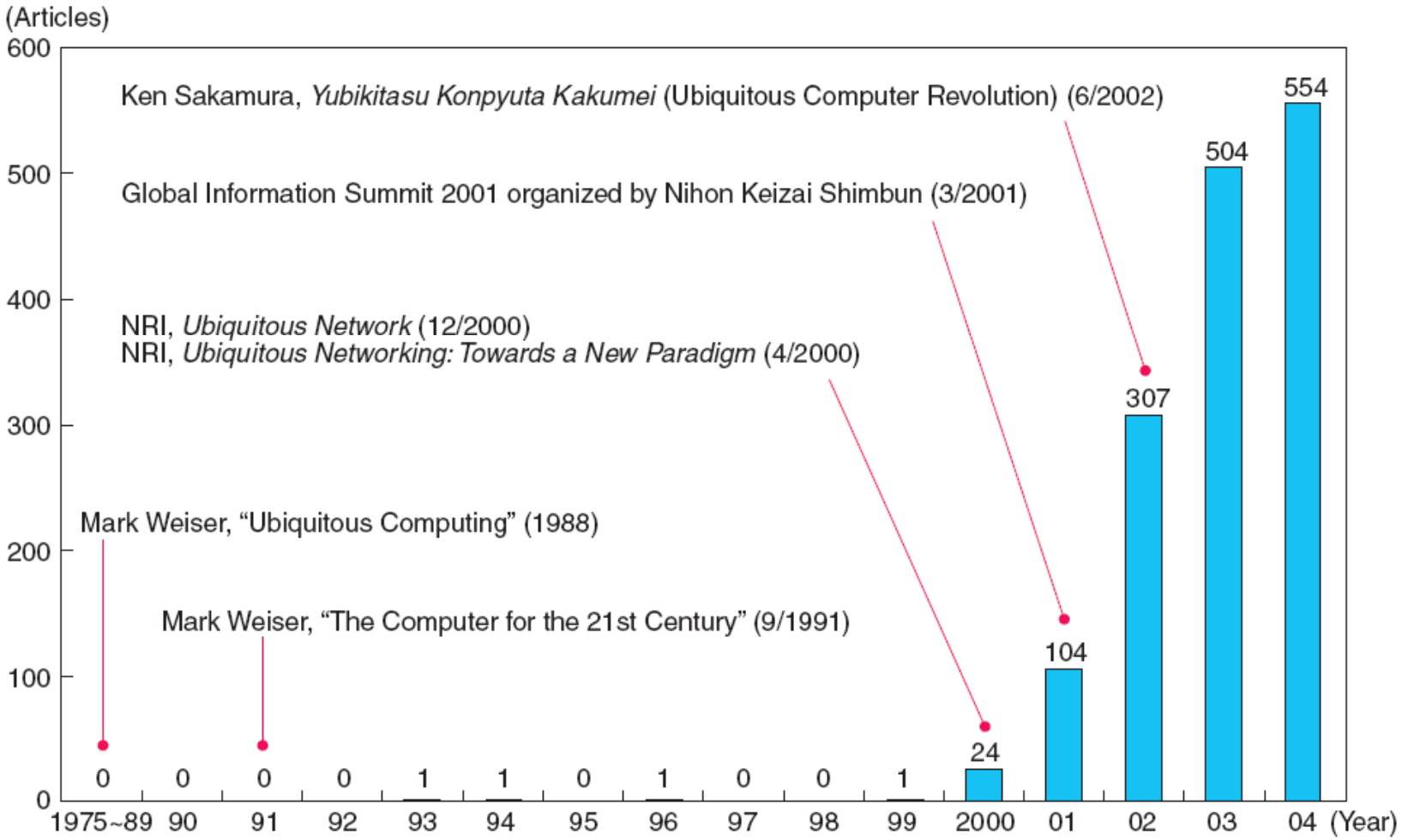
All winds are blowing in the same direction – toward Ubiquity!

Definitions for Different Terminologies

- "**u-Japan**" is what Japan will be like in 2010 when information and communications technology (ICT) will be applied toward resolving various problems in society. It is based on four principles: ubiquitous (connects everyone and everything); universal (can be easily used by the elderly, etc.); user-oriented (based on users' viewpoints); and unique (creative and vigorous). *(Information and Communications in Japan, Ministry of Internal Affairs and Communications, Japan, White Paper, 2005)*
- **"Ubiquitous Network Society (UNS)":** Scenario in which there is "anywhere and anytime access for anyone and anything" *(Ubiquitous Network Society: The Case of Japan, 2005)*
- **"Ubiquitous computing":** A new era in which computer devices will be embedded in everyday objects invisibly at work d the environment around us; in which intelligent, intuitive interfaces will make computer devices simple to use and unobtrusive; and in which communication networks will connect these devices together to facilitate anywhere, anytime, always-on communications. *(Marc Weiser ,1991)*
- **"Ambient Intelligence"** is a distributed network of intelligent devices that provides us with information, communication and entertainment." *(Emile Aarts , Rick Harwig, "Ambient Intelligence", URL: http://www.research.philips.com)*
- **"Ambient Intelligence"** is a network of hidden intelligent interfaces that recognize our presence and mould our environment to our immediate needs." *(John Horvath, Telepolis, Making Friends with Big brother, URL: http://www.heise.de/tp/english/inhalt/te/12112/1.html)*
- **"Ambient Intelligence"** refers to an exciting new paradigm in information technology, in which people are empowered through a digital environment that is aware of their presence and context and is sensitive, adaptive and responsive to their needs, habits, gestures and emotions." *("Ambience Project", URL: http://www.extra.research.philips.com/euprojects/ambience)*

2.3 Global Scenarios: Global Initiatives

Frequency of Appearance of Ubiquitous-Related Articles in Three Japanese Financial Newspapers (Nihon Keizai Shimbun, Nikkei Business Daily & Nikkan Kogyo Shimbun)

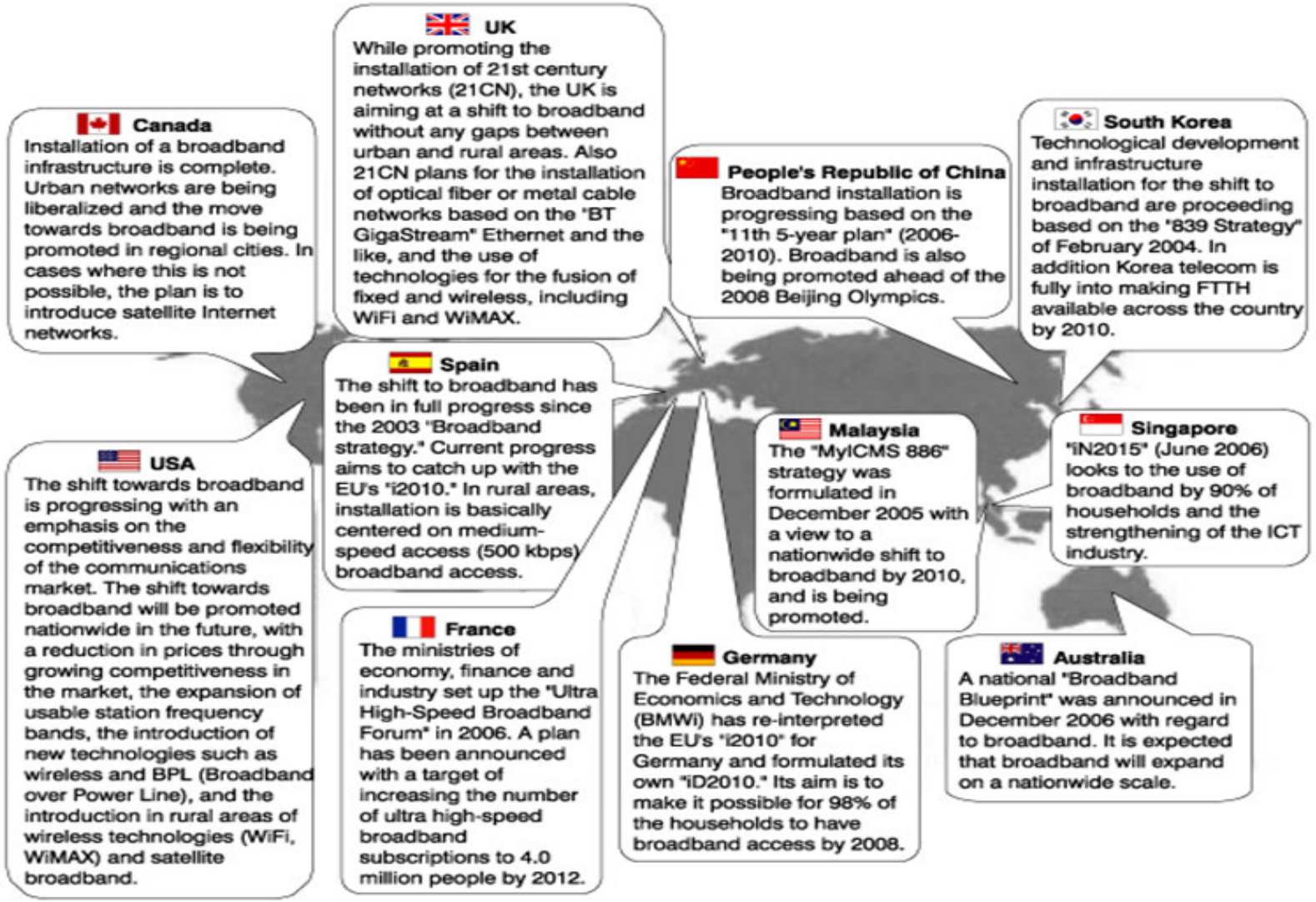


Source:

- *"Japan's National IT Strategy and the Ubiquitous Network", Nomura Research Institute, NRI Papers, November, 2005.*

2.3 Global Scenarios: Global Initiatives

Broadband initiatives by countries

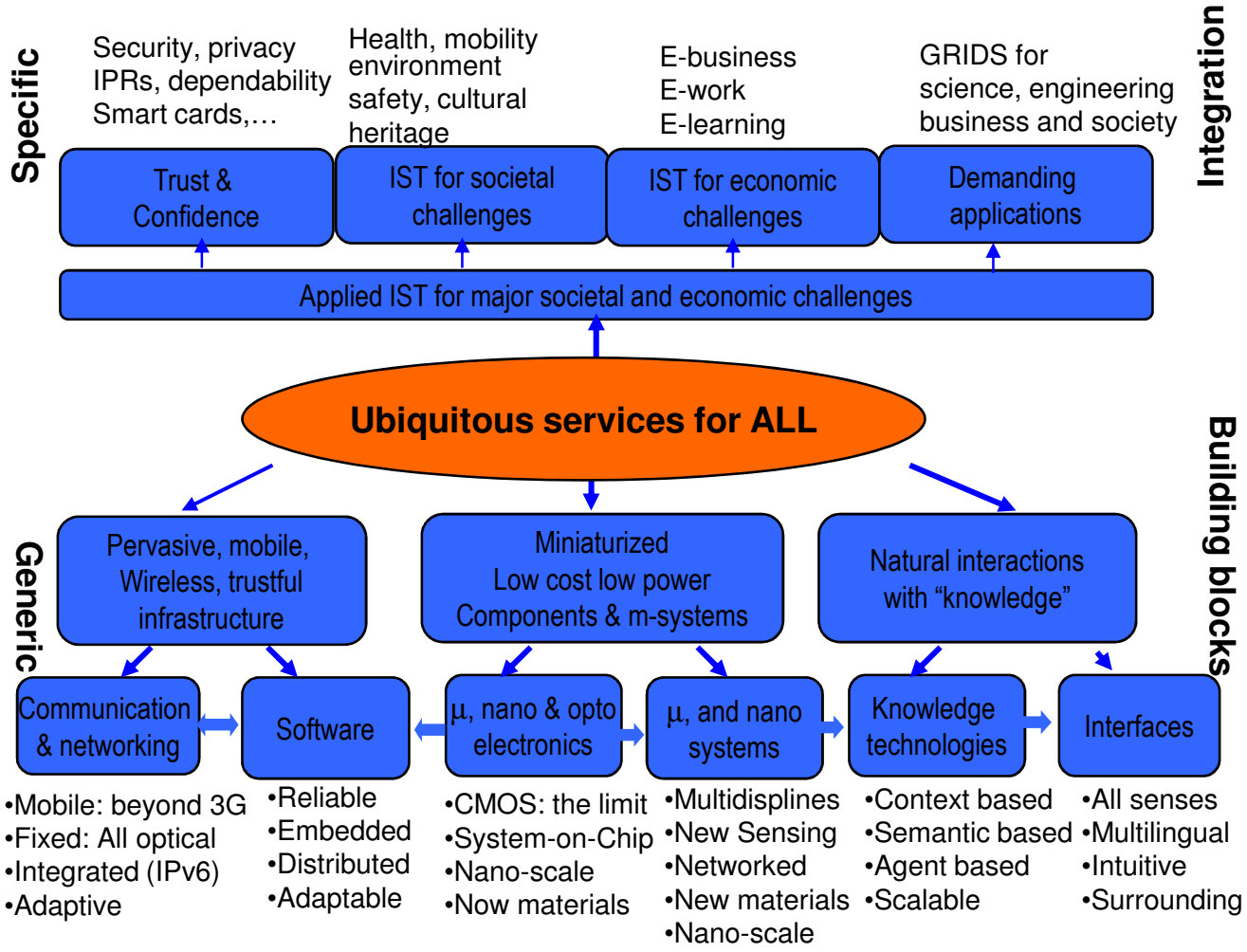


Source:

- *"Moving towards establishing a Usage Environment for Next-Generation Broadband Technology" , Study Group Report, MIC Communications News, Vol. 18, No. 13, 12 Oct 2007*

2.3 Global Scenarios: Global Initiatives

EU Ubiquitous Communications Framework (FP6)



Ubiquitous networks consist of building blocks more than just the communications that provide the trusted infrastructures.

Microelectronics, nanoelectronics and optoelectronics enable miniaturization of low cost and low power devices, including the sensing devices, to be embedded pervasively.

The intelligence of the ubiquitous networks is realized mainly by semantic technology coupled with intelligent user interfaces.

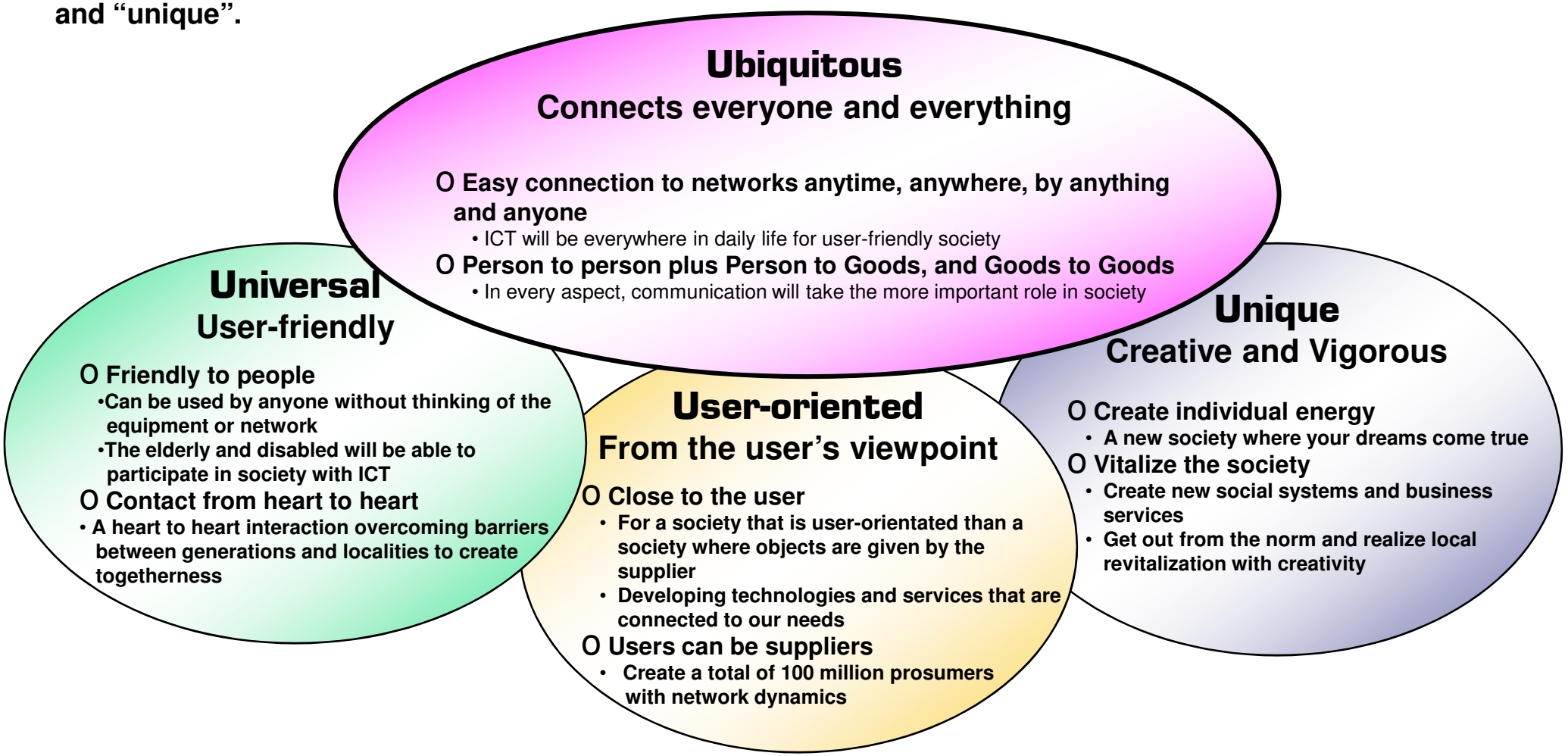
Ubiquitous networks are services oriented which provide services from the societal and economic aspects.

Source:
- *"Technologies for Major Business and Work Challenges", IST in FP6 Introduction for Consultation Meeting Series 2001*

2.3 Global Scenarios: Global Initiatives

The u - Japan Concept

u-Japan is characterized by "person-to-person" and "goods-to-goods" communications with the "ubiquitous" playing the key role among the four principles—"ubiquitous," "universal," "user-oriented," and "unique".

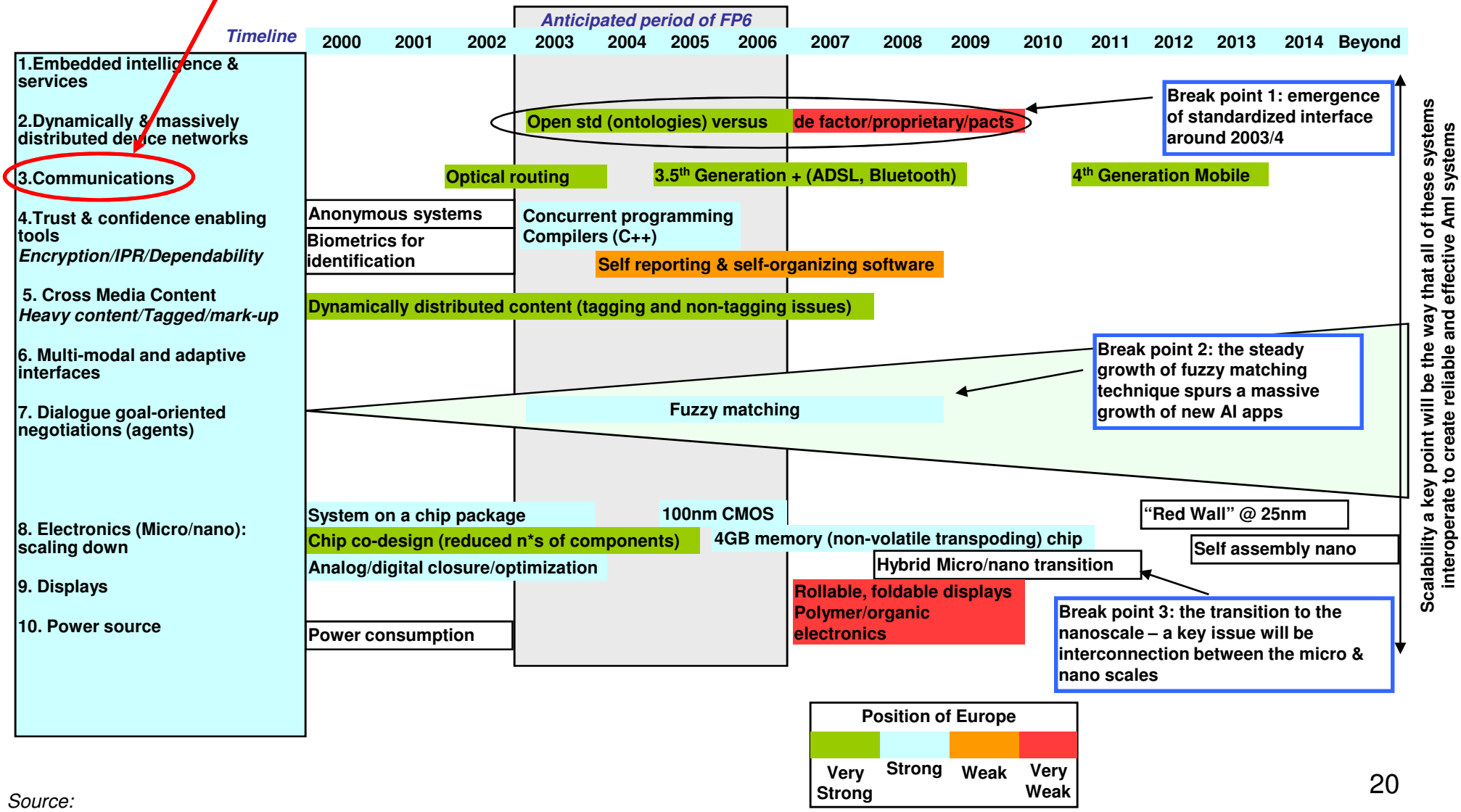


Source:

- ***"Trends in ICTPolicy in Japan",*** *September 7, 2006, Hiromu Momma, Director, Space Communications Research Office, Information and Communications Policy Bureau, Ministry of Internal Affairs and Communications*

2.3 Global Scenarios: Global Initiatives (AmI Techno Line)

ISTAG "Ambient Intelligence 2010" roadmap showing the necessary technology development toward AmI. Communication is one of the building blocks .



Source:
- *ISTAG "Ambient Intelligence 2010"*

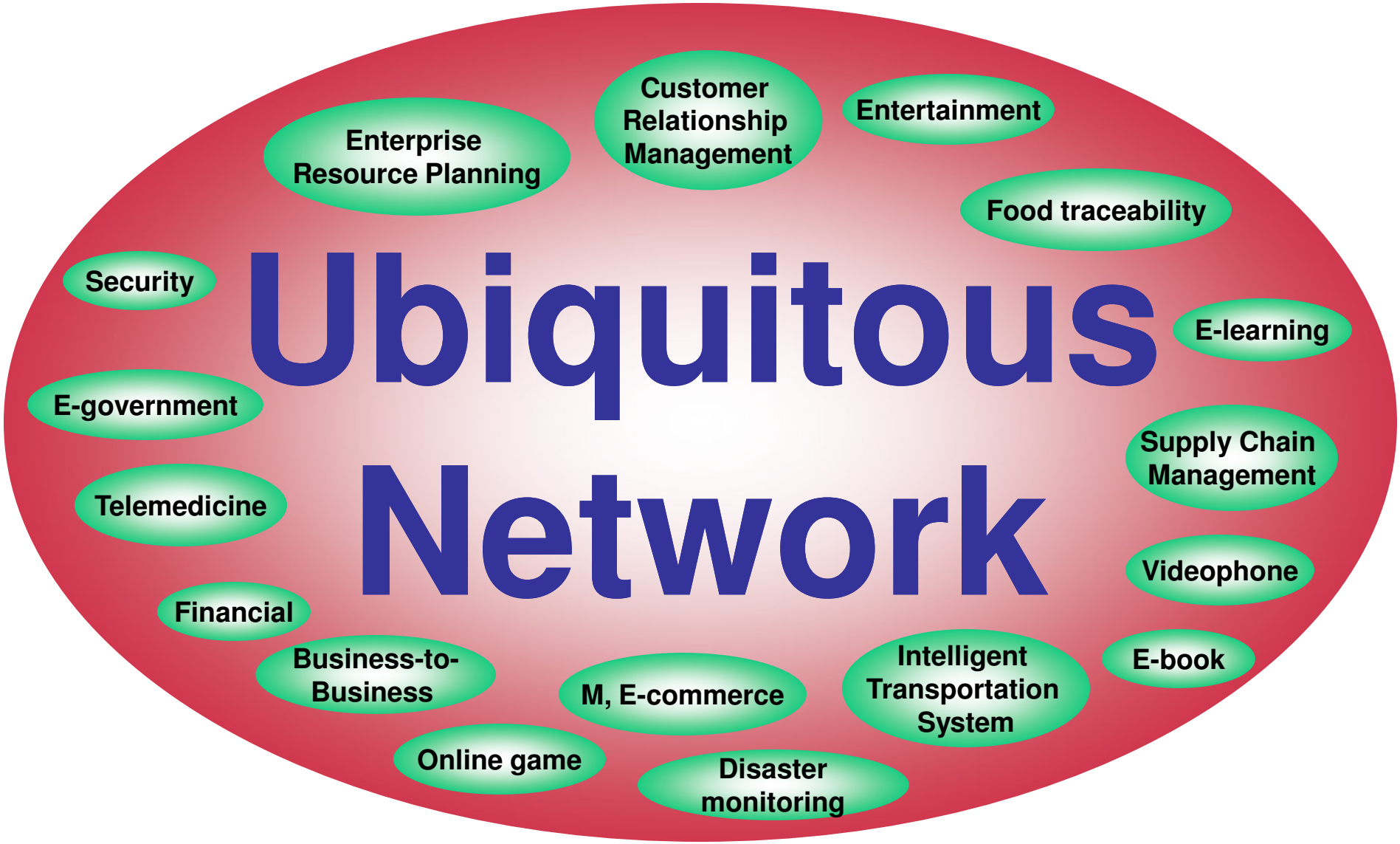
3.1 Malaysia Scenarios: Government Initiatives

No	Government Initiatives	Communications Related Areas
1	Vision 2020	• Developing Malaysia into an industrialized country • Transform Malaysia's production-centric economy (P-Economy) to a knowledge-based economy (K-Economy)
2	The MyICMS886 Strategy	• SERVICES: High Speed Broadband, 3G & Beyond, Mobile TV, Digital Multimedia Broadcasting, Digital Home, Short Range Communications (e.g. RFID-based), VoIP/Internet Telephony, Universal Service Provision • INFRASTRUCTURE: Multiservice Convergence Networks, 3G Cellular Networks, Satellite Networks, Next Generation Internet Protocol (IPv6), Home Internet Adoption, Information & Network, Security • GROWTH: ICT Education Hub, Digital Multimedia Receivers (set top box), Communication Device (e.g. VoIP phones), Embedded Components, Devices (e.g. RFID)
3	IMP3	• To narrow the digital divide • To roll out the initiatives on tele-health and e-commerce • To extend broadband coverage progressively to major industrial areas • To develop web-based shared facilities to provide technology-related information and services

3.1 Malaysia Scenarios: Government Initiatives *(continued)*

No	Government Initiatives	Communications Related Areas
4	Ninth Malaysia Plan (RMK9)	• Enhancing Malaysia's position as a global ICT and multimedia hub • Expanding the communications network to ensure more equitable access to information and services • Intensifying efforts at bridging the digital divide • Developing the existing cybercities as well as promoting new cybercentres and MSC multimedia applications • Accelerating e-learning acculturation • Enhancing information security
5	National Broadband Plan	• Bringing the benefits of high speed broadband services at the "top" end to spur Malaysia as a global communications and multimedia hub with digital cities sprouting all over the country powered by a centrally planned wired mesh networks. Malaysian urbanites would be living in a very much more intelligent home lifestyle. Many states will have their own MSC Cybercity developments which will be the focal point of a knowledge-based ubiquitous society; and • Bringing the benefits of high speed broadband to each the residential homes in the rest of the country moving from the cities into the suburbs, towns, villages and eventually the rural communities.
6	Strategic ICT Roadmap for Malaysia	• Wireless Sensors Networks (ICT infrastructure) • Predictive Analytics (ICT info-structure) • 3-Dimensional Internet (Multimedia Digital Content)

3.2 Malaysia Scenarios: Expected Services from Ubiquitous Network



4.1 Roadmap: Targeted Scenarios by Stages

Dimension	Short Term* (0-3 years)	Mid Term* (3-5 years)	Long Term* (>5 years)
User Aspects	• Users always-connected to the networks (at least at dense area), enjoying broadband roaming on single mobile appliance, having access to certain services in triple-play • Users enjoy reliable, secure and affordable services with flexible and unified billing • Users enjoy user-friendly access and services • Certain degree of home automation is available	• Users enjoy high speed access, even at less dense areas, to a wide variety of services including real time multicast video streaming, mobile TV, and interactive games • Users transparently access to a wide variety of personalized services through different type of networks • Users enjoy seamless mobility and indoor/outdoor connectivity, able to utilize mobile banking securely • Home automation is personalized • Quadruple-play is bundled as a service	• Ubiquitous network society where there is a guaranteed high speed network connection anytime and anywhere (even at least dense areas) to anything and anyone, having access to any type of personalized services and broadband content with highly trustworthy, at both nomadic and high speed travel, with a single high performance appliance or miniaturized devices • Users are able to enjoy HDTV • Integrated home automation available • Connectivity is free

*: Time line for completion

4.1 Roadmap: Targeted Scenarios by Stages

Dimension	Short Term* (0-3 years)	Mid Term* (3-5 years)	Long Term* (>5 years)
Technology Aspects	• 2 Mbps access available at major cities; 512 kbps access available at rural areas	• Networks capable of handling a rapid increase in bandwidth demand • Different type of networks are connected through IP-based platform capable of supporting different data format • Network systems and devices with low standby power & high efficiency • Ultra-high speed short range transmission by high frequency band (mm-wave) • Sensor networks capable of recognizing and responding to different individuals • Seamless handover between heterogeneous networks • Fixed-mobile networks converged seamlessly • Multimode device • 10 Mbps access available at major cities; 2 Mbps access available at rural areas	• Scalable and resilient networks capable of handling unlimited number of appliances • Networks autonomously and efficiently respond to different type of service requests • Radio spectrum usage optimized by cognitive radio transmission where appliances autonomous select & adapt to the surrounding radio frequency spectrum usage • Common & integrated platform with high security, high efficiency & interoperability • Networks recoverable/restorable autonomously • 1 Gbps access available at major cities at low speed, 100 Mbps at high speed; 10 Mbps access available at rural areas; 2 Mbps access available at highways • Non-GPS location aware

***: Time line for completion**

4.2 Roadmap: Technologies Challenges

Challenges	Technologies
Mobility	• Mobile Internet Protocol (MIP) • Network Mobility (NEMO) • Internet Protocol version 6 (IPv6) *(Refer to Appendices D & E for National IPv6 Roadmaps)* • Worldwide Interoperability for Microwave Access (WiMax) • 3rd Generation (3G) • Session Initiation Protocol (SIP)
Multi-mode	• 3G/WiMax/WiFi/GPS/GSM/LTE • Low power/high speed processor • System on Chip (SoC) • Microelectronics, Nanotechnology, embedded technology • Software Defined Radio (SDR) • Digital Signal Processing (DSP)
Context aware	• Surveillance systems • Location base services • Global positioning system • Motion detection • Telemetry • Wireless sensor networks (WSN) & Radio Frequency Identification (RFID) • WiFi positioning

Challenges	Technologies
Personalization	• Graphical user interface (GUI) • User called ring tone • WSN & RFID • Short range devices (SRD) • IPv6 *(Refer to Appendices D & E for National IPv6 Roadmaps)*
Embeddedness	• Global positioning system • Bluetooth • RFID • Microelectromechanical systems (MEMS) • Nanotechnology • Machine to machine (M2M) • IPv6 *(Refer to Appendices D & E for National IPv6 Roadmaps)*
Wearable	• RFID, ID tagging, smart tag • Robotic walker • Implant chip • IPv6 *(Refer to Appendices D & E for National IPv6 Roadmaps)*
Heterogeneity	• MIP • SIP • WiFi-WiMAX • Seamless hand-off

4.2 Roadmap: Technologies Challenges

Challenges	Technologies
Convergence	• SDR • Multimode devices • IP Multimedia Subsystem (IMS)
Open platform	• Open source software (OSS) • Android • Linux Mobile (LIMO) • Software architecture: SDK (software development kits), Linux, • Hardware: SDR
Self-*	• IPv6 *(Refer to Appendices D & E for National IPv6 Roadmaps)* • Network management • Packet inspection • Bio-inspired networks • Radio access networks • Auto link budget (cell optimization) • Intelligent base station
Autonomous	• Bio-inspired networks
Reconfigurable	• SDR • Cognitive Radios (CR) • Field-programmable gate array (FPGA) • Programmable DSP • High speed A/D and D/A

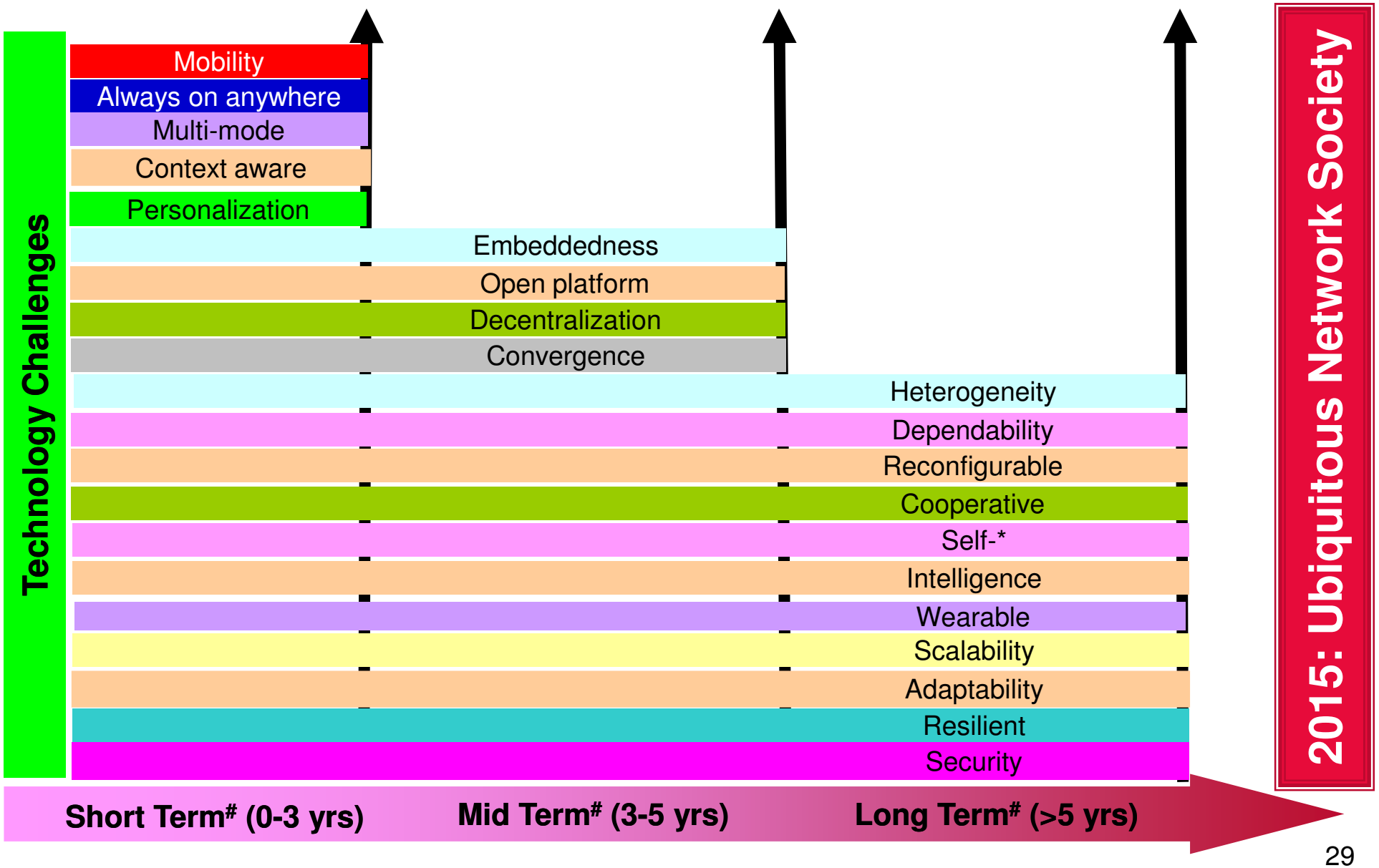
Challenges	Technologies
Resilient	• Forward Error Correction (FEC) • Turbo coding • Low-density parity-check (LDPC) • Interference cancellation • Channel estimation • Hybrid Automatic Repeat ReQuest (HARQ) • Cognitive radios • Smart antenna
Security	• Internet Protocol Security (IPSec) • Cryptography, Key management • SIM-based • Wi-Fi Protected Access (WPA) • Wired Equivalent Privacy (WEP) • Secure Sockets Layer (SSL) • Frequency hopping (Probabilistic Method)
Dependability	• Redundancy • Fault tolerant • Diversity (transmission/network) • Distributed architecture
Higher data rate	• Multiple-input multiple-output (MIMO) • Interference cancellation

Self-*: Self-organizing, self-optimization, self-management, self-adaptive, self-healing, etc.

4.2 Roadmap: Technologies Challenges

Challenges	Technologies
Cooperative	• Cross layer design • Peer to peer • Multi-transceivers • CR • Radio access technologies
Decentralization	• Ad-hoc networks • Mobile Ad-hoc Networks (MANET) • Vehicular Ad-hoc Network (VANET) • Routing and service recovery • NEMO • Bio-inspired networks
Scalability	• WPAN/WLAN/WRAN/WWAN • Spectrum sharing • IPv6 *(Refer to Appendices D & E for National IPv6 Roadmaps)* • Channel coding • CR antenna • Bio-inspired network
Adaptability	• Adaptive modulation & coding (up to 64QAM) • SDR • Scalable OFDM • Scalable bandwidth • FPGA • Power control • Bio-inspired networks

4.3 Roadmap by Technology Challenges



 # Time required to make the technology ready or commercially viable

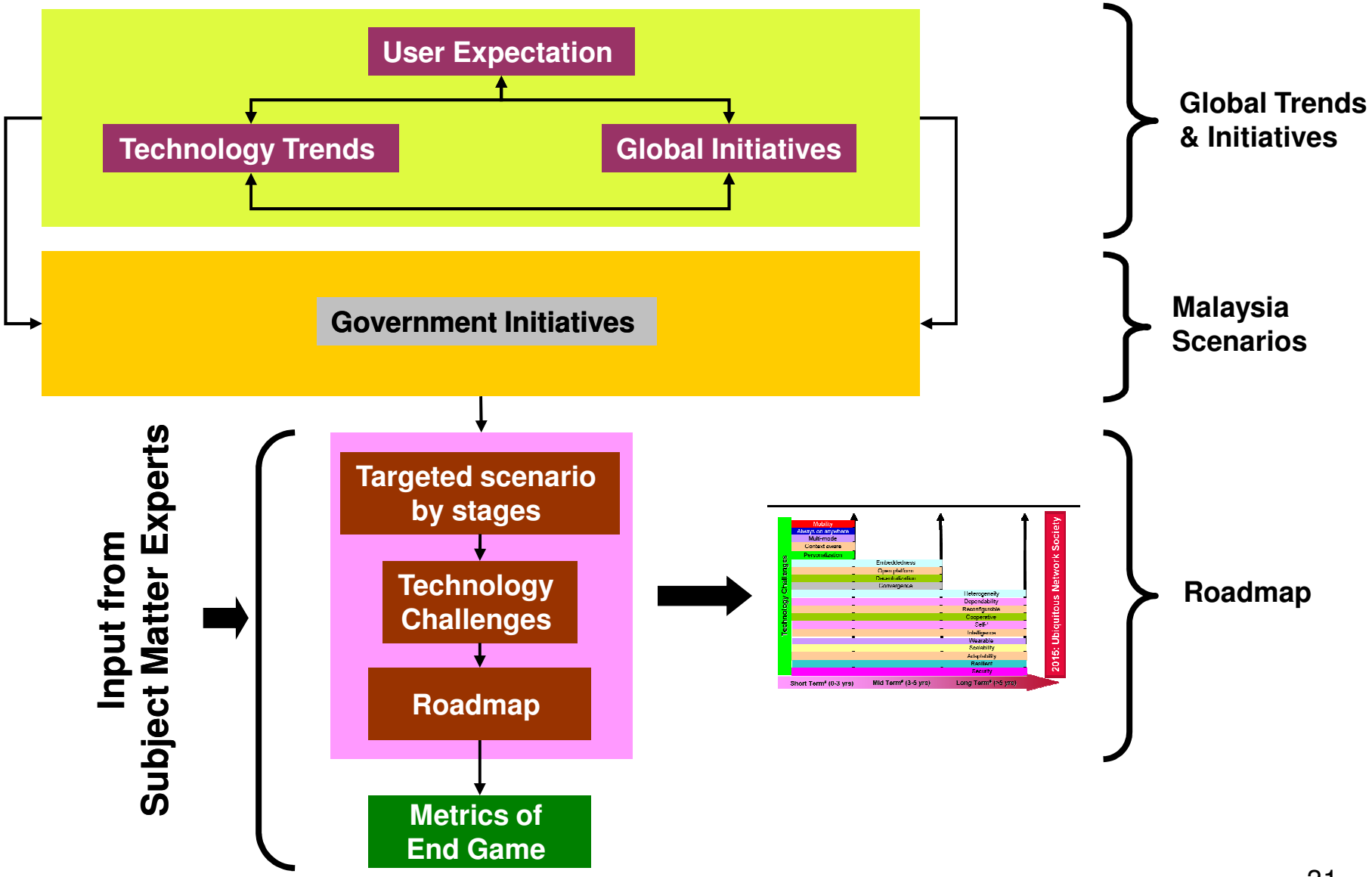
5. Conclusion

Transition to Ubiquitous Network Society is a long term perspective and a long term evolution. It requires continuous advancement of various technology areas, including, but not limited to nanotechnology, semantics technology, security technology, communications technology, etc. The communications technology will play a major role in providing the necessary infrastructure for ubiquitous network.

A consensus has been achieved in the National Wireless Communications Technology Roadmap workshop that user expectation and experiences are more important than the underline technologies. It is also worth noting that the European 7th Framework Program (FP7) does not really stress on technologies but on challenges and services that can achieve the best impact on the European economy and society.

The roadmap, outlining the technology challenges, provides a guideline for Malaysia research organizations to navigate the wireless research avenue in an effective way, to determine the most suitable strategy for their research works as well as the most effective methods deploying that technology toward achieving Ubiquitous Network Society.

Appendix A - Methodology



Appendix B - List of Roadmap Contributors

No.	Name	Affiliation
1	Ala Abdullah	Universiti Sains Malaysia
2	Amir Rasif Abdul Razak	Telekom Malaysia
3	Amirul Ahmad	Malaysian Technical Standards Forum Bhd
4	Assoc. Prof. Dr. Nor Kamariah Nordin	University Putra Malaysia
5	Badrul Zaman Adnan	MIMOS Bhd
6	Chia Ching King	Telekom Malaysia
7	Danabalan Amirthaligam	Nokia-Siemens Networks
8	Dr. Fadlee Abdul Rashid	Universiti Putra Malaysia
9	Dr. Faidz Abd Rahman	MMU
10	Dr. Farhat Anwar	International Islamic University Malaysia
11	Dr. MD Rafiqul Islam	International Islamic University Malaysia
12	Dr. Raja Syamsul Raja Amir	Universiti Putra Malaysia
13	Dr. Tommi Chen	ipVx Sdn Bhd
14	Dr. Chandran Elamvazuthi	MIMOS Bhd
15	Dr. Choong Khong Neng	MIMOS Bhd
16	Dr. Daniel Wong	IEEE
17	Dr. David Chieng	British Telecom
18	Dr. Gopakumar Kurup	MIMOS Bhd
19	Dr. Hafizal Mohamad	MIMOS Bhd
20	Dr. K Arichandran	MIMOS Bhd

Appendix B - List of Roadmap Contributors *(continued)*

No.	Name	Affiliation
21	Dr. Ling Teck Chaw	Malaysia University of Science and Technology
22	Dr. Mazlan Abbas	MIMOS Bhd
23	Dr. Sahar A. Al-Talib	MIMOS Bhd
24	Dr. Sathish Chandran	MIMOS Bhd
25	Dr. Sharifah Kamilah bt Syed Yusof	Universiti Teknologi Malaysia
26	Dr. Sim Moh Lim	Multimedia University
27	Dr. Teyo Tuan Chin	MIMOS Bhd
28	Dr. Varun Jeoti	Universiti Tenaga Nasional
29	Fauziah Abdullah	Alcatel-Lucent
30	Gijsson Chow	IPWireless Pte Ltd
31	Gopinath Rao Sinniah	MIMOS Bhd
32	Hesham Soliman	Elevate Technologies
33	Imran Mohd Ibrahim	University Teknikal Malaysia Melaka
34	Jaafar Hj Mohamad Abd Bakar	Telekom Malaysia
35	Ling Teck Chaw	Universiti Malaya
36	Lum Kai Mun	Izzinet Sdn Bhd
37	Mohamed b. Awang Lah	Jaring
38	Mohammed Hakim bin Othman	University Teknikal Malaysia Melaka
39	Mohd Isa Bin Wahab Ali	Telekom Malaysia
40	Mohd Saifulbaha	Jaring

Appendix B - List of Roadmap Contributors *(continued)*

No.	Name	Affiliation
41	Moriani Mohamad	DiGi
42	Nidhal A. S. Odeh	MIMOS Bhd
43	Nor Hisham bin Haji Khamis	Universiti Teknologi Malaysia
44	Ong Kheok Chin	Motorola
45	Phang Keat keong	Universiti Malaya
46	Prof. Dr. Zaiki Awang	Universiti Teknologi Mara
47	Prof. Ir. Dr. Ahmad Faisal Mohd Zain	University Tun Hussein Onn Malaysia
48	Assoc. Prof. Dr Tan Chong Eng	University Malaysia Sarawak
49	Prof. Dr. Borhanuddin Mohd Ali	MIMOS Bhd
50	Prof. Dr. Mazlina Esa	Universiti Teknologi Malaysia
51	Prof. Dr. Norsheila Bt Fisaal	Universiti Teknologi Malaysia
52	Prof. Dr. Tharek Abd Rahamn	Universiti Teknologi Malaysia
53	Rashid A. Saeed	MIMOS Bhd
54	Ravindran Ramesan	Maxis
55	Razif Rahim	Telekom Malaysia
56	Rohazli Adam	Celcom (Malaysia) Berhad
57	Shahid Siddiqui	Agilent Technologies
58	Siow Ching Kang	Izzinet Sdn Bhd
59	Syed Ahmad Anas b. Syed Omar	Packet One Networks (M) Sdn Bhd

Appendix C – Glossary

1G	1st Generation
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
ADSL	Asymmetric Digital Subscriber Line
AMPS	Advanced Mobile Phone System
ANA	Autonomic Network Architecture
API	Application Programming Interface
BTS	Base Transceiver Station
CASCADAS	Component-ware for Autonomic Situation-aware Communications, and Dynamically Adaptable Services
CDMA	Code Division Multiple Access
CoE	Center of Excellence
CR	Cognitive Radio
DOCSIS	Data Over Cable Service Interface Specification
DSP	Digital Signal Processing
DVB-H	Digital Video Broadcasting - Handheld
ETACS	Extended Total Access Communication System
ETSI	European Telecommunications Standards Institute
EUDCH	Enhanced Uplink Data Channel
EV-DO	Evolution-Data Optimized
FEC	Forward Error Correction
FIRE	Future Internet Research and Experimentation
FPGA	Field-programmable Gate Array
FTTH	Fiber to the Home
GPRS	General Packet Radio Service

Appendix C – Glossary

GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface
HARQ	Hybrid Automatic Repeat ReQuest
HDTV	High-definition Television
HSPDA	High-Speed Downlink Packet Access
IMP3	Third Industrial Master Plan
IMS	IP Multimedia Subsystem
IMT-2000	International Mobile Telecommunications-2000
IMT-Advanced	International Mobile Telecommunications - Advanced
IP	Internet Protocol
IPSec	Internet Protocol Security
IPv6	Internet Protocol version 6
ISTAG	Information Society Technologies Advisory Group
ITU-R	The International Telecommunication Union Radiocommunications
JTACS	Japanese Total Access Communication System
LDPC	Low-density Parity-check
LIMO	Linux Mobile
LTE	Long Term Evolution
M2M	Machine to Machine
MANET	Mobile Ad-hoc Networks
MEMS	Microelectromechanical Systems
MIMO	Multiple-input Multiple-output
MIP	Mobile Internet Protocol
MSC	Multimedia Super Corridor

Appendix C – Glossary

MyICMS 886	Malaysian Information, Communications and Multimedia Services 886
NEMO	Network Mobility
NFC	Near Field Communications
NGN	Next Generation Networks
OSS	Open Source Software
PSTN	Public Switched Telephone Network
QoS	Quality of Services
RFID	Radio Frequency Identification
SDR	Software Defined Radio
SIP	Session Initiation Protocol
SoC	System on Chip
SRD	Short Range Devices
SSL	Secure Sockets Layer
TIA	Telecommunications Industry Association
UNS	Ubiquitous Network Society
UWB	Ultra Wideband
VANET	Vehicular Ad-hoc Network
VPN	Virtual Private Networks
VSR	Very Short Reach
WCDMA	Wideband Code Division Multiple Access)
WEP	Wired Equivalent Privacy
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Networks
WWAN	Wireless Wide Area Networks
WPA	Wi-Fi Protected Access
WSN	Wireless Sensor Networks